7-2008

Flourescent penetrant inspection—cleaning study update

David J. Eisenmann
Iowa State University, djeisen@iastate.edu

Lisa H. Brasche
Iowa State University, lbrasche@iastate.edu

FLUORESCENT PENETRANT INSPECTION—CLEANING STUDY UPDATE

D. Eisenmann and L. Brasche

Citation: AIP Conf. Proc. **1096**, 549 (2009); doi: 10.1063/1.3114303
View online: http://dx.doi.org/10.1063/1.3114303
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1096&Issue=1
Published by the American Institute of Physics.

FLUORESCENT PENETRANT INSPECTION - CLEANING STUDY UPDATE

D. Eisenmann and L. Brasche

Iowa State University, Center for NDE, Applied Sciences Complex II, 1915 Scholl Road, Ames, IA 50011

ABSTRACT. Fluorescent penetrant inspection (FPI) is widely used in the aviation industry and other industries for surface-breaking crack detection. As with all inspection methods, adherence to the process parameters is critical to the successful detection of defects. There is variety of lubricants and surface coatings used in the aviation industry which must be removed prior to FPI. Before the FPI process begins, components are cleaned using a variety of cleaning methods which are selected based on the alloy and the soil types which must be removed. It is also important that the cleaning process not adversely affect the FPI process. From the first three phases of this project it has been found that a hot water rinse can aid in the detection process when using this nondestructive method.

Keywords: Fluorescent Penetrant, Cleaning, Titanium, Nickel
PACS: 81.70 Fy

INTRODUCTION

Effective fluorescent penetrant inspection (FPI) to detect surface breaking cracks begins with a clean, dry part. There are a variety of cleaning methods available for use by the aviation industry in preparation for FPI and other inspection and repair processes. In a recent study of cleaning practices, it was found that some cleaning methods were detrimental to the brightness of FPI indications, particularly for titanium alloys. For many of the titanium samples, the crack indication was not detectable after contamination and cleaning using typical industrial cleaning practices. In later discussions with experts from industry, it was suggested that a chemical reaction could be a potential cause of the loss of crack indication. When titanium oxide is exposed to alkaline solutions, the following chemical reaction occurs:

$$2NaOH + TiO_2 \rightarrow Na_2TiO_3 + H_2O \text{ (Possible Hydrate)} \quad (1)$$

CP1096, *Review of Quantitative Nondestructive Evaluation Vol. 28,*
edited by D. O. Thompson and D. E. Chimenti

This reaction causes titanium oxide (TiO_2) to expand to sodium titinate (Na_2TiO_3) which could seal the cracks even tighter and potentially add water to the inside of the crack. The purpose of this program was to explore possibilities for more effective cleaning preparations in FPI.

EXPERIMENTAL RESULTS

Phase One

For this phase of the study, Titanium samples were selected based on their history in a previous program, in which contamination studies were done using titanium and nickel. In the prior work, typical cleaning processes were effective in removing contamination from nickel without adversely affecting the FPI response as evaluated using brightness measurements; this was not the case for titanium samples.

To better understand the factors affecting titanium, an initial study was planned using 12 samples from the early ETC work. This served as a preliminary study for follow-on work planned using pristine samples. Six samples that were not responsive (did not show indications after FPI due to clogged cracks) and six samples that did not show adverse effects to the cleaning study were split into two groups as listed in Fig. 1. Three non-responsive samples and three responsive samples were sent to each of the two participating OEMs for the study to determine if there were ways to recover lost cracks without damage (such as materials loss or crack contamination) to the samples themselves.

Although all of the crack indications from this phase were recovered, not all were recovered on the first attempt, nor were all samples returned to their initial brightness condition as shown in Fig. 1:

- Sample 01-018 was recovered, but it is very faint.
- Sample 01-037 was recovered in the third attempt.
- Samples 01-053 and 00-091 were recovered, but it appears that the salt bath removed a considerable amount of the surface material, making the crack wider than the initial width.
- Sample 01-014 appeared wider than normal as well.

There were some concerns over the sample appearance during the study, although samples did not change appearance until undergoing the salt baths and second cleaning by the participating groups.

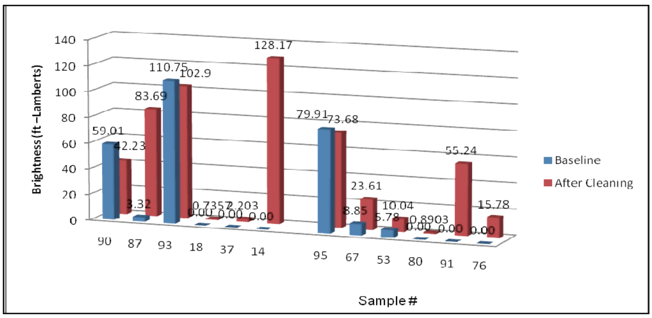

FIGURE 1. Phase One results showing initial baseline brightness values and final result brightness values.

Phase Two

For the second phase of this research, a new set of samples was fabricated using a low cycle fatigue process. The samples set consisted of 20 pieces of Titanium 6-4. The sizes of the samples were comparable to the first set in that they were 6" long, 1" wide, and ½" in thickness. The crack size for the new sample set was 0.060", with a tolerance of ± 0.010".

In the second phase a cleaning matrix was developed to map out the steps to be followed. The sample set consisted of 12 samples to be tested, and the remaining eight to be set aside for any future need. Of the 12 samples to be tested, nine were heat treated at 975° Fahrenheit in room atmosphere for 96 hours and oven cooled to simulate the high temperature exposure found in service. Results of the heat treating process are found in Figs. 2 and 3.

In the second phase of the study, the results were less than desirable, with only two of the nine heat treated samples crack indications being able to be detected. Of the three non-heat treated samples, two indications were detected to at or near original brightness, and one indication was detected, but with minimal brightness.

The primary reason for the non-recovery of the heat treated samples is the hard Alpha case that was formed on the surface of the samples during the heat treatment process. The various amounts of hard alpha that formed can be seen in the center of the sample set in Fig.2, illustrated by the lack of FPI response.

The negative effect of hard alpha is that it acts almost as an oxide, covering the surface of the sample and, in effect, filling and covering the crack, inhibiting detection by fluorescent penetrant inspection. The primary reason for the diminished brightness of sample 516 from group one is the formation of titinate from the alkaline cleaning, as described in the technical summary of the report.

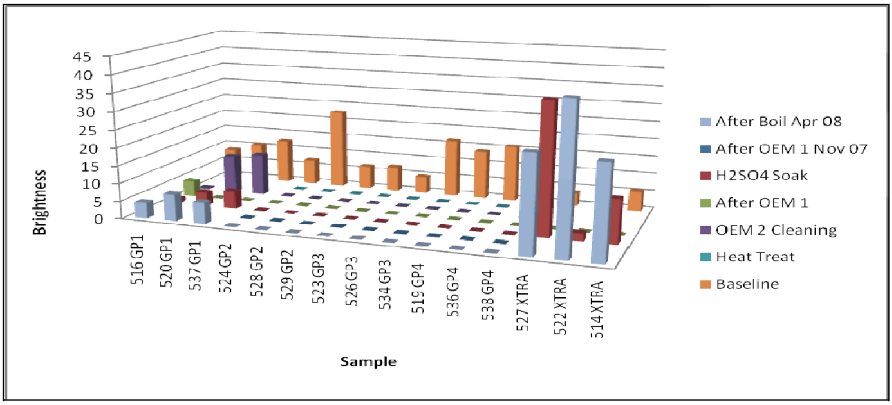

FIGURE 2. Phase Two Results showing all processes during this phase.

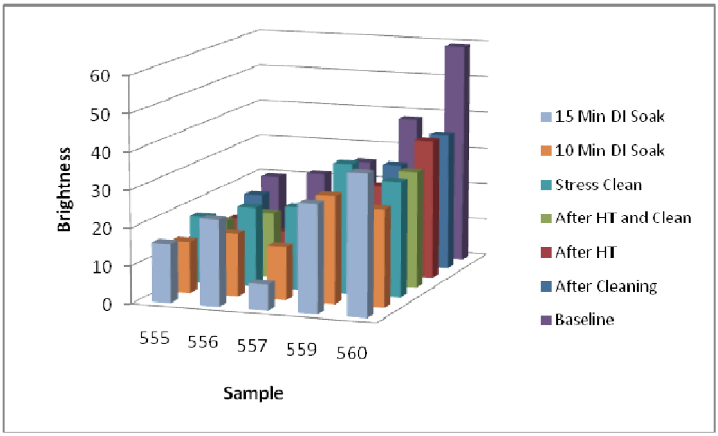

FIGURE 3. Phase Three results after heat treatment, cleaning and hot DI water soak.

Phase Three

In the third and most recent phase of this program new samples were again created using identical methods for generating low cycle fatigue cracks as used in the previous phases. Sample material was Titanium 6Al 4V, with the sample dimensions for phase three being the same as for the previous phases as well, with crack lengths ranging from 0.055" to 0.065". Samples were processed for cleaning using an industry standard cleaning process for titanium and checked for FPI responsiveness, after each step was completed (see Figure 3 above and Table 1 below for the process samples were placed through, along with brightness indications).

All samples were heat treated at 800 degrees Fahrenheit for 96 hours after the first clean to determine if there would be a detrimental response to the exposure to high temperature. In all but one sample there was a decrease in brightness after heat treatment, but the change in brightness was not as noticeable after heat treatment as it was for the initial cleaning. Once the samples had been heat treated, they were put through the cleaning process once more, and the indications improved slightly, possibly due to the chemical exposure of the cleaning process itself.

To improve the response of the samples at this point in the process, all the samples were placed into fixtures which applied a bending force of approximately 80 percent of yield, with the thought being that if there were something in the crack prohibiting the penetrant from getting into the flaw, a stress cleaning may help to eliminate this foreign material. With an improvement in response after stress cleaning, consensus of the group lead to the theory that the end of the cleaning process was not thoroughly removing the cleaning materials from the samples. The final two steps in this phase have been to place the samples through a hot water rinse after the cleaning process. The final results showed that a 15 minute rinse in hot water above 150 degrees Fahrenheit improved the response of the samples to the cleaning process.

TABLE 1. Process for Phase Three Cleaning.

Sample	Baseline Average	After Cleaning	After Heat Treatment	Clean, Heat Treatment, Clean	Stress Clean	10 min DI Soak	15 min DI Soak	20% Turco 4181L
555	19.816667	16.9995	12.5999	14.4928	18.0344	13.7793	15.7298	10.7634
556	21.3927	13.4305	9.8315	17.4884	21.3174	16.8155	22.959	10.4836
557	25.647633	20.9679	14.3493	3.5413	22.248	14.2318	6.8827	0.0551
559	38.406133	27.7409	24.1816	19.5298	34.7176	28.5997	28.7932	18.1533
560	59.316867	36.8943	37.3229	31.1061	30.7778	25.8836	37.4902	15.1915

CONCLUSIONS

Given the variety of cleaning methods in existence for preparation of parts for FPI, and the cast number of parts utilizing the FPI method, determining the least detrimental method of cleaning for Titanium alloys is necessary for the continued safety of air travel. It is evident from this two phase study that there are several different factors that affect the detectability of surface cracks with FPI. As seen in phase one, there are methods that exist in present cleaning practices that can greatly affect the surface of a sample, as seen in those samples subject to the molten salt bath. In phase two of the study, the adverse effects of temperature and atmosphere may also mask surface breaking cracks. It was also shown in phase two that the alkaline cleaning process may form titinates which may hinder crack detection as well. In phase three of the project, the effects of high temperature and the possible causes for reduced indications were explored. It was found that a hot water rinse for at least 15 minutes in hot water above 150 degrees Fahrenheit improved the response of the samples to the cleaning process. Further work is being performed to look into the exact parameters for the rinse (time and temperature) as well as the effects that various alkaline cleaners and concentrations have on detectability of indications using fluorescent penetrant inspection.

ACKNOWLEDGMENTS

This material is based upon work supported by the Federal Aviation Administration under Contract #DTFA03-98-D-00008, Delivery Order #0016 and performed at Iowa State University's Center for NDE as part of the Center for Aviation Systems Reliability program in cooperation with partners at Boeing Commercial, Boeing Phantom Works, Delta Airlines, United Airlines, Rolls Royce, General Electric, Pratt & Whitney, Honeywell, D&W Enterprises, and Sherwin.

REFERENCES

1. AMS 2647B – Fluorescent Penetrant Inspection Aircraft and Engine Component Maintenance.
2. "Engineering Studies of Cleaning and Drying Processes in Preparation for Fluorescent Penetrant Inspection (FPI)," FAA Report published Spring 2003.
3. L. Brasche, B.F. Larson, and R. Lopez, "A Review of Recent Research Studies of Cleaning and Drying in Preparation for Fluorescent Penetrant Inspection – Parts I and

II" Review of Progress in QNDE, Vol. 22, edited by D.O. Thompson and D.E. Chimenti, 2006.

4. D. Eisenmann, L. Brasche, and R. Lopez, "Preliminary Results of Cleaning Process for Lubricant Contamination" Review of Progress in QNDE, Vol. 26, edited by D.O Thompson and D.E. Chimenti, 2006.